code stamped on each injector and/or affixing a bar code to the injector which is indicative of the selected trim category, in the same manner as described above (MEUI embodiment).

In step **344**, the trim category is read from each injector and is inputted, which may be scanned in via bar code reader/scanner **336**, to control module **314**, in a manner identical to that described in the mechanically-actuated electronically-controlled injector embodiment.

The remaining steps of the present invention **346–350** occur during operation of fuel system **200**. In step **346**, control module **314** calculates, for each injector **202** in fuel system **200**, a respective fuel delivery and actuating fluid pressure signals for controlling the injectors based on operating parameters including S_{1-8} and nominal timing and delivery characteristic values for hydraulically-actuated electronically-controlled fuel injectors.

In step **348**, a respective fuel delivery signal for each injector is adjusted based on respective timing and delivery offset values associated with a trim category into which the respective fuel injector has been categorized in step **340**. Use of offset values is identical to that described above in connection with the mechanically-actuated electronically-controlled embodiment of the present invention.

In step **350**, each injector is controlled in accordance with a respective adjusted fuel delivery signal and the actuating fluid pressure signal. Although current technology limits the practical extent to which changes in pressure may be made on an individual injector basis, it is expected that such technology will be available in the near future and thus such use of the pressure parameter clearly falls within the spirit and scope of this invention.

One of the many advantages of the present invention is the ability to eliminate the affects of variability introduced by the manufacturing and assembly process of an apparatus, such as a fuel injector or other fuel system component. This reduction or elimination of operating characteristic variability is obtained both simply, and inexpensively, and reduces to a large extent the end of line rejection of assembled apparatus that would ordinarily not be of any value due to large variations in performance (i.e., would have to be scrapped).

Other aspects, objects, and advantages of this invention can be obtained from a study of the drawings, the disclosure and the appended claims.

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We claim:

1. A method of operating an apparatus of the type having a nominal resultant characteristic at a plurality of operating conditions when controlled in accordance with a control signal, comprising the steps of:

measuring a resultant characteristic associated with the apparatus at a plurality of operating conditions;

adjusting the control signal as a function of the variation between the measured resultant characteristics and the nominal resultant characteristic and as a function of the operating condition of said apparatus; and

controlling the apparatus in accordance with the adjusted signal such that the resultant characteristics of the apparatus when operated approach the nominal resultant characteristics.

2. The method of claim 1, further comprising the step of:

associating the resultant characteristics measured in said measuring step with the apparatus.

3. The method of claim 2, wherein the control signal is generated by a control means having a memory means, and

wherein said associating step includes the substep of storing data indicative of the measured resultant characteristics of the apparatus in the memory means.

4. The method of claim 2 wherein said associating step includes the substep of permanently recording data indicative of the measured resultant characteristics of the apparatus on said apparatus.

5. The method of claim 4, wherein the control signal is generated by a control means, and wherein said associating step includes the substeps of reading the data recorded on the apparatus and inputting the read data into the control means.

6. The method of claim 1 wherein said adjusting step includes the substeps of categorizing the apparatus, based on the measured resultant characteristics, into one of a plurality of trim categories wherein each category has an associated offset value, and modifying the control signal as a function of the offset value.

7. The method of claim 6 wherein said modifying step is further performed as a function of an actual operating condition.

8. The method of claim 1 wherein said adjusting step includes the substeps of determining the relationship between the nominal resultant characteristics as a function of the control signal and the measured resultant characteristics of the apparatus as a function of the control signal, and modifying the control signal based upon the determined relationship.

9. The method of claim 8 wherein said modifying step is further performed as a function of an actual operating condition.

10. A method of operating a plurality of electronically-controlled fuel injectors of the type having a nominal start of injection characteristic wherein fuel injection is controlled by a fuel delivery signal, comprising the steps of:

measuring, for each injector, a respective start of injection characteristic;

associating, for each injector, the measured start of injection characteristic with the respective injector;

adjusting, for each injector, the fuel delivery signal as a function of the variation of the respectively associated measured start of injection characteristic from the nominal start of injection characteristic;

controlling each injector in accordance with the respective adjusted fuel delivery signal to reduce start of injection variation.

11. The method of claim 10, wherein the fuel delivery signal is generated by a control means having a memory means, and wherein said associating step includes the substep of storing data indicative of the measured start of injection characteristic of each injector in the memory means.

12. The method of claim 10, wherein said associating step includes the substep of permanently recording data indicative of the measured start of injection characteristic of each injector on a respective injector.

13. The method of claim 12, wherein said associating step includes the substep of categorizing each injector, based on a respective measured start of injection characteristic, into one of a plurality of trim categories wherein the permanently recorded data is a trim category designation.

14. The method of claim 12, wherein the fuel delivery signal is generated by a control means, and wherein said associating step includes the substeps of reading the data recorded on the injector and inputting the read data into the control means.

15. The method of claim 14, wherein said permanently recording data substep is performed by bar coding the

respective data indicative of the measured start of injection on each injector to generate a respective bar code, and wherein said reading and inputting substeps are performed by scanning the bar codes recorded on the injectors, interpreting each bar code to reconstruct the data indicative of the measured start of injection characteristic, and transmitting the reconstructed data into the control means.

16. The method of claim 14 wherein said permanently recording data substep is performed by affixing, for each injector, a resistor having a resistance value indicative of the measured start of injection of the respective injector, and wherein said reading and inputting sub-steps are performed by sensing, for each injector, the resistance value of the respectively affixed resistor, and interpreting, for each injector, the sensed resistance value to reconstruct the data indicative of the measured start of injection characteristic.

17. The method of claim 13 wherein each category has an associated offset value, and wherein said adjusting step includes the substep of modifying the fuel delivery signal for each injector as a function of a respective offset value.

18. A method of operating a plurality of electronically-controlled fuel injectors wherein fuel injection is controlled by a fuel delivery signal, the injectors being of the type having a nominal delivery characteristic as a function of operating conditions, comprising the steps of:

measuring, for each injector, a respective delivery characteristic at a plurality of operating conditions;

associating, for each injector, the measured delivery characteristic with the respective injector;

adjusting for each injector, the fuel delivery signal as a function of the variation of the respectively associated measured delivery characteristic from the nominal delivery characteristic at each operating condition of the injector;

controlling each injector in accordance with the respective adjusted fuel delivery signal to minimize injector to injector delivery variation.

19. The method of claim 18, wherein said associating step includes the substep of permanently recording data indicative of the measured delivery characteristic of each injector on a respective injector.

20. The method of claim 19, wherein the fuel delivery signal is generated by a control means and wherein said associating step includes the substeps of reading the data recorded on the injector and inputting the read data into the control means.

21. The method of claim 20 wherein said permanently recording data substep is performed by bar coding the respective data indicative of the measured delivery on each injector to generate a respective bar code, and wherein said reading and inputting substeps are performed by scanning the bar codes recorded on the injectors, interpreting each bar code to reconstruct the data indicative of the measured delivery characteristic, and transmitting the reconstructed data into the control means.

22. The method of claim 20 wherein said permanently recording data substep is performed by affixing to each injector a resistor having a resistance value indicative of the measured delivery characteristic of the respective injector, and wherein said reading and inputting substeps are performed by sensing, for each injector, the resistance value of the respective affixed resistor and interpreting, for each injector, the sensed resistance value to reconstruct the data indicative of the measured delivery characteristic.

23. The method of claim 18, wherein the fuel delivery signal is generated by a control means having a memory means, and wherein said associating step includes the sub-

step of storing data indicative of the measured delivery characteristic of each injector in the memory means.

24. The method of claim 19 wherein said associating step includes the substep of categorizing each injector, based on a respective measured delivery characteristic, into one of a plurality of trim categories wherein the permanently recorded data is a trim category designation.

25. The method of claim 24 wherein each category has an associated offset value, and wherein said adjusting step includes the substep of modifying the fuel delivery signal for each injector as a function of a respective offset value.

26. A method of operating a plurality of electronically-controlled fuel injectors wherein fuel injection is controlled by a fuel delivery signal generated by a control means having a memory means, the injectors being of the type having a nominal start of injection characteristic and nominal delivery characteristic, comprising the steps of:

measuring, for each injector, a respective start of injection characteristic and delivery characteristic;

categorizing each injector into one of a plurality of trim categories as a function of the variation of the measured start of injection and delivery characteristics from the respective nominal start of injection and delivery characteristics, each trim category having an associated start of injection and delivery offset value;

recording the category into which each injector was categorized in said categorizing step on a respective injector;

storing the respective category recorded on each injector in the memory means;

calculating the fuel delivery signal as a function of actual operating conditions based on nominal start of injection and delivery characteristics;

adjusting the fuel delivery signal for each injector as a function of the respective start of injection and delivery offset values;

controlling each injector in accordance with the respective adjusted fuel delivery signal to reduce start of injection and delivery variation.

27. The method of claim 26 wherein the injectors are hydraulically-actuated injectors which are further controlled

by an actuating fluid pressure command signal, the method further comprising the step of adjusting the actuating fluid pressure command signal for each injector as a function of the respective start of injection and delivery offset values.

28. The method of claim 26 wherein said measuring step is performed at a plurality of operating conditions, and wherein said adjusting step includes the substep of further adjusting the fuel delivery command signal as a function of an actual operating condition.

29. The method of claim 26 wherein said recording step includes the substep of affixing, for each injector, a respective bar code that is indicative of the category into which the respective injector was categorized.

30. The method of claim 26 wherein said recording step includes the substep of affixing, for each injector, a respective resistor having a resistance value that is indicative of the category into which the respective injector was categorized.

31. A system for controlling the delivery of fuel through a plurality of fuel injectors to an engine, each injector being of the type characterized by at least one observed performance parameter, comprising:

sensor means for detecting a plurality of operating parameters and generating a respective plurality of operating parameter signals indicative of the parameter detected;

control means responsive to said operating parameter signals for generating a base fuel delivery signal for each injector; each fuel injector being coupled with said control means to receive a respective base fuel delivery signal for controlled fuel delivery to the engine;

memory means coupled with said control means for storing trim signals for each injector, said trim signals being derived from observed performance parameter values taken at a plurality of operating conditions;

means for communicating said trim signals to said memory means;

said control means being responsive to said trim signals for trimming said base fuel delivery signal for each injector as a function of said trim signals and as a function of said operating parameter signals for reducing performance parameter variation.

* * * * *

32. An apparatus control system, comprising:

an apparatus controllable by a control signal and having a resultant characteristic associated with the apparatus in a plurality of operating conditions;

a data recording associated with the apparatus containing data indicative of the measured resultant characteristics of the apparatus in machine readable form; and

a control module that receives the data indicative of the measured resultant characteristics from the data record, and produces the control signal as a function of the measured resultant characteristics to control the apparatus.

33. The apparatus control system of claim 32, wherein the control module comprises memory means for storing the data indicative of the measured resultant characteristics of the apparatus, and data transfer means for reading said data from the data recording and storing said data in the memory means.

34. The apparatus control system of claim 32, wherein the data recording containing the data indicative of the measured resultant characteristics of the apparatus is permanently recorded on the apparatus.

35. A method of operating an apparatus of the type having a nominal resultant characteristic at a plurality of operating conditions when controlled in accordance with a control signal, comprising:

reading data indicative of a resultant characteristic associated with the apparatus that has been measured at a plurality of operating conditions;

adjusting the control signal as a function of the measured resultant characteristics; and

controlling the apparatus in accordance with the adjusted signal such that the resultant characteristics of the apparatus when operated approach the nominal resultant characteristics.

36. The method of claim 35, wherein the control signal is generated by a control means having a memory means, and further comprising storing data indicative of the measured resultant characteristics of the apparatus in the memory means.

37. The method of claim 36, further comprising categorizing the data indicative of the measured resultant characteristics of the apparatus into one of a plurality of trim categories wherein each category has an associated offset value, and modifying the control signal as a function of the offset value.

38. The method of claim 37, wherein said modifying step is further performed as a function of an actual operating condition.

39. The method of claim 38 wherein adjusting the control signal includes determining the relationship between the nominal resultant characteristics as a function of the control signal and the measured

resultant characteristics of the apparatus as a function of the control signal, and modifying the control signal based upon the determined relationship.

40. The method of claim 39 wherein modifying the control signal is further performed as a function of an actual operating condition.

41. A method of operating a plurality of electronically-controlled fuel injectors of the type having a nominal start of injection characteristic wherein fuel injection is controlled by a fuel delivery signal, comprising:

for each injector, reading a respective start of injection characteristic from a respective data recording associated with each respective injector;

adjusting, for each injector, the fuel delivery signal as a function of the variation of the respectively associated measured start of injection characteristic from the nominal start of injection characteristic; and

controlling each injector in accordance with the respective adjusted fuel delivery signal to reduce start of injection variation.

42. The method of claim 41, wherein the fuel delivery signal is generated by a control means having a memory means, and further comprising storing data indicative of the measured start of injection characteristic of each injector in the memory means.

43. The method of claim 42, wherein each said respective data recording is permanently recorded on each said respective injector.

44. The method of claim 43, further comprising categorizing each injector, based on a respective measured start of injection characteristic, into one of a plurality of trim categories, and wherein the permanently recorded data is a trim category designation.

45. The method of claim 42, wherein each said respective data recording is permanently recorded on each said respective injector as a respective bar code, and wherein said data recordings are read by scanning the bar codes recorded on the injectors, interpreting each bar code to reconstruct the data indicative of the measured start of injection characteristic, and transmitting the reconstructed data into the control means.

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